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(54) Surveillance method of optical communication line

(57) To enable the surveillance of a long-distance optical fiber line that a method using the reflection lights and Rayleigh backscatter lights cannot cover, the invention provides a method as follows. A plurality of optical reflection elements P1 - Pn are interposed in the optical fiber line at each specific distance. Each of the optical reflection elements P1 - Pn reflects only a light signal of one of specific wavelengths λ1 - λn on a constant level. Light pulses of the specific wavelengths λl - λn are transmitted to the optical fiber line to measure intensities of the light pulses reflected by the optical reflection elements P1 - Pn. From the measurement, the surveillance of the optical fiber line can be done between the transmitter and each of positions of the optical reflection elements P1 - Pn. According to this method, the reflectance of the optical reflection elements P1 - Pn can be set to 100%, and the surveillance becomes possible even if the optical fiber line exceeds 200km.

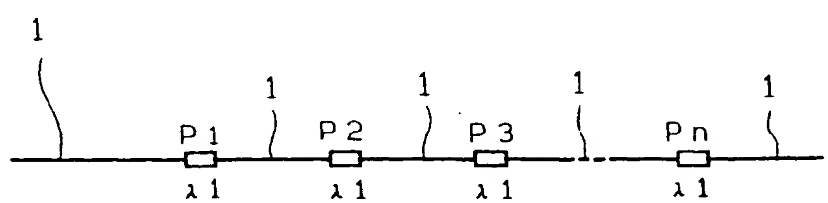

FIG.1 (A)

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a surveillance method for detecting faults and locations in fault of an optical fiber line of a nonrepeating optical communication line, Bi-directional optical communication line, or optical communication line provided with an optical amplifier repeater, and a surveillance method of the gain and loss and the like of optical circuits including optical amplifiers interposed in the optical fiber line.

Description of the Related Art

Fig. 8 illustrates a construction of a optical communication line to which a conventional surveillance method is applied. As shown in this figure, a transmitter terminal equipment 110 is connected to one end of an optical fiber line 101, and a receiver terminal equipment 120 is connected to another end of the optical fiber line 101 so as to communicate between both of the equipment. A remotely pumped optical amplifier 100 is interposed in the optical fiber line 101. The remotely pumped optical amplifier 100 is constructed so as to cascade an erbium doped fiber (EDF) 103 and an optical isolator 102.

Furthermore, the transmitter terminal equipment 110 is provided with a transmitter 111 for transmission a light signal modulated by a transmission data to the optical fiber line 101 and a optical time domain reflectometer (OTDR) 112 that transmits a light pulse to the optical fiber line 101, measures an reflection lights and Rayleigh backscatter lights generated therein, and based on the measurement surveys the optical fiber line 101 on the side of the transmitter terminal equipment 110.

Furthermore, the receiver terminal equipment 120 is provided with an pump light source 122 for supplying an pump light to the remotely pumped optical amplifier 100, an wavelength multiplexer 121 for transmitting the pump light from the pump light source 122 to the optical fiber line 101, a receiver 123 for receiving and demodulating the light signal transmitted through the optical fiber line 101, and a OTDR 124 for surveying the optical fiber line 101 on the side of the receiver terminal equipment 120 based on the measurement of the reflection lights and Rayleigh backscatter lights.

Moreover, the optical isolator 102 disposed before the EDF 103 having an optical amplification function is to prevent the deterioration of transfer characteristics of the remotely pumped optical amplifier 100 due to the reflection lights and Rayleigh backscatter lights and the like generated in the optical fiber, and it has a function to confine the direction in which light signals propagate.

Although Fig. 8 shows only one-way (the ascent or descent) of the communication line, a Bi-directional optical communication line may be formed using the same construction as in Fig. 8.

The optical fiber line 101 is a optical communication line as described above, and the length of the line is, for example, about 400km. In this case, the remotely pumped optical amplifier 100 consisting of the EDF 103 and the optical isolator 102 is placed within about 100km from the receiver terminal equipment 120 in consideration of a propagation loss of an pump light propagating through the optical fiber line 101 from the pump light source 122.

Fig. 9(A) shows a signal intensity attenuating dependently on the propagation distance of a light signal propagating through the optical fiber line 101. As shown in this figure, the intensity of the light signal attenuates in proportional to the propagation distance owing to the propagation loss given by the optical fiber line 101. The light signal, however, is optically amplified by the remotely pumped optical amplifier 100 to recover the signal intensity at the position where the remotely pumped optical amplifier 100 is interposed.

The surveillance method in the optical communication line thus constructed will now be described. The OTDR 112 provided in the transmitter terminal equipment 110 transmits a light pulse to the optical fiber line 101, and measures the intensity of a weak reflection lights and Rayleigh backscatter lights on the time domain as a portion of the Rayleigh scattering light generated by fluctuation of refractive index in the optical fiber line 101, returning to the input.

Since the measurement dynamic range of the OTDR 112 is about 40dB at highest, it is impossible to measure the whole section of the nonrepeating optical communication line over 400km. That is, if the propagation loss of the optical fiber is 0.2dB/km, the measurable range of the reflection lights and Rayleigh backscatter lights is about 200km. The reflection lights and Rayleigh backscatter lights received over 200km becomes so weak to be buried under noises and discrimination is almost impossible.

In this manner, the OTDR 112 provided in the transmitter terminal equipment 110 surveys the optical fiber line 101 within about 200km from the transmitter terminal equipment 110 by measuring an reflection lights and Rayleigh backscatter lights.

The OTDR 124 provided in the receiver terminal equipment 120 transmits a light pulse to the optical fiber line 101, and measures the intensity of an reflection lights and Rayleigh backscatter lights on the time domain returning to the input. In this case, since the optical isolator 102 is interposed at a position of about 100km from the receiver terminal equipment 120, the light pulse for measurement does not propagate over the optical isolator 102; and therefore, the OTDR 124 surveys the optical fiber line 101 up to the optical isolator 102.

In the conventional optical communication line, the optical fiber line 101 is surveyed as described above,

and the range of about 100km from a position over 200km from the transmitter terminal equipment 110 to a position where the optical isolator 102 is interposed becomes out of surveillance, as shown in Fig. 9(B).

Still, if the receiver 123 surveys a reception level in order to survey the operation of the EDF 103 of the remotely pumped optical amplifier 100, it is impossible to discriminate whether the fluctuation of the reception level results from the transfer characteristics of the EDF 103 or from the optical fiber line 101.

SUMMARY OF THE INVENTION

The present invention has been made in view of the foregoing problems, and an object of the present invention is to provide a surveillance method that enables to survey a optical communication line through the whole line and to survey the transfer characteristics when an optical amplification means is interposed in the optical fiber line.

In order to accomplish the aforementioned object, in the first surveillance method of an optical communication line according to the present invention, optical reflection elements are interposed at constant intervals, or at a plurality of optional positions in an optical fiber line, and every optical reflection element therein reflects only a light signal of one specific wavelength on a constant level. And, a light signal of the specific wavelength is transmitted to the optical fiber line to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights. On the basis of the measurement and/or observation, sections in fault are determined and a state of the line is surveyed.

In the second surveillance method of an optical communication line according to the present invention, optical reflection elements are interposed at constant intervals or at a plurality of optional positions in an optical fiber line, and each of the optical reflection elements reflects only a light signal of one of specific wavelengths different from one another on a constant level. And, the light signals of the specific wavelengths different from one another that the optical reflection elements each reflect are transmitted to the optical fiber line, to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights. On the basis of the measurement and/or observation, sections in fault are determined and a state of the line is surveyed.

In the third surveillance method of an optical communication line according to the present invention, optical reflection elements are interposed at constant intervals or at a plurality of optional positions in an optical fiber line, and every optical reflection element therein reflects only a light signal of one specific wavelength on a constant level. Furthermore, optical reflection elements are interposed at constant intervals or at a plurality of optional positions in the optical fiber line, and each of the optical reflection elements reflects only a light signal of one of specific wavelengths different from one another on a constant level. And, the light signals of the specific wavelengths that the optical reflection elements each reflect are transmitted to the optical fiber line to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights. On the basis of the measurement and/or observation, sections in fault are determined and a state of the line is surveyed.

In the fourth surveillance method of an optical communication line according to the present invention, in an optical fiber line in which an optical fiber having a rare earth element doped to have an optical amplification function is disposed in the optical fiber line, optical reflection elements are interposed before and behind the optical fiber having the optical amplification function. Each of the optical reflection elements reflects only a light signal of one of specific wavelengths different from each other on a certain level. And, the light signals of the specific wavelengths that the optical reflection elements reflect are transmitted to the optical fiber line, to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights. On the basis of the measurement and/or observation, a state of operation of the optical fiber having the optical amplification function is surveyed.

Furthermore, in the foregoing surveillance method of an optical communication line, the optical reflection elements are optical fiber gratings.

According to the present invention as described above, since optical reflection elements reflecting light signals of specific wavelengths are interposed in the optical communication line and each of intensities of reflected lights from the optical reflection elements is measured, an optical communication line can be surveyed which is too long to cover for the surveillance method using the reflection lights and Rayleigh backscatter lights.

Furthermore, since optical reflection elements are interposed before and behind the optical amplification means and each of intensities of reflected lights from the optical reflection elements is measured, the level difference of light signals before and behind the optical amplification means can be measured so that the transfer characteristics of the optical amplification means can be surveyed.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be fully understood from the detailed description given below and from the accompanying drawings of the preferred embodiments of the invention, which, however, should not be taken to limit the specific embodiment, but are for explanation

and understanding. in which:

Fig. 1(A) and Fig. 1(B) are charts for explaining the principle of a surveillance method of an optical communication line relating to the present invention;

Fig. 2(A) and Fig. 2(B) are charts for explaining the principle of another surveillance method of an optical communication line relating to the present invention;

Fig. 3(A) is a chart showing a construction of a nonrepeating optical communication line in which a surveillance method of the optical communication line relating to the present invention is applied. Fig. 3(B) - Fig. 3(E) are charts showing waveforms of reflected lights from optical reflection elements;

Fig. 4(A) is a chart showing a construction of a nonrepeating optical communication system in which another surveillance method of the optical communication line relating to the present invention is applied. Fig. 4(B) and Fig. 4(C) are charts showing components of wavelengths propagating through the receiving side optical fiber line, and a chart showing waveforms received by the OTDR;

Fig. 5 is a chart showing a construction of a nonrepeating optical communication system in which the surveillance methods of the optical communication line illustrated in Fig. 3 and Fig 4 are applied;

Fig. 6(A) is a chart for explaining an optical fiber grating. Fig. 6(B) is a chart showing a reflection characteristics of an optical fiber grating;

Fig. 7 is a chart showing a construction of the OTDR;

Fig. 8 is a chart showing a construction of a conventional nonrepeating optical communication system;

Fig. 9(A) is a chart showing an intensity curve of a signal propagated in the conventional nonrepeating optical communication system. Fig. 9(B) is a chart showing the surveillance range by the reflection lights and Rayleigh backscatter lights.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The principle of the surveillance method of an optical communication line according to the present invention will be described with reference to Fig. 1 and 2.

Fig. 1 illustrates the principle of the surveillance method of an optical communication line relating to the first embodiment, and Fig. 2 illustrates the principle of the same relating to the second embodiment.

As shown in Fig. 1(A), a plurality of optical reflection elements P1, P2, P3, ··· Pn are interposed, for example, at every specific distance in an optical fiber line 1. These optical reflection elements P1, P2, P3, ··· Pn reflect only a light signal of one specific wavelength, and the optical fiber gratings are applied to these in an example. The optical reflection elements P1, P2, P3, ··· Pn shown in Fig. 1 are designed to reflect a light signal of a wavelength λ1, and all the wavelengths that the optical reflection elements P1, P2, P3, ··· Pn each reflect are designed to be identical.

The pulse tester transmits a light pulse of the specific wavelength λ1 to the optical fiber line 1 in the direction of the arrow shown in Fig. 1(A). And, the light pulse of the specific wavelength λ1 propagates through the optical fiber line 1, a part of the light pulse transmits corresponding to a transmittance of the optical reflection element P1 through a position where the optical reflection element P1 reflecting the light pulse of the wavelength λ1 is interposed in the optical fiber line 1, and the rest reflects at the foregoing position. The transmitted light further propagates, a part of the transmitted light transmits through a position where the optical reflection element P2 is interposed, and the rest reflects at the position. Thus, the transmitted light propagates toward the right on the drawing, and every time when the light transmits through the optical reflection elements P1, P2, P3, ··· Pn, the light intensity attenuates corresponding to the reflectance thereof.

The reflected lights each return toward the OTDR, as shown in Fig. 1(A). Since the optical reflection elements P1, P2, P3, ··· Pn are interposed in the returning path of the reflected lights, the reflected lights fall on the optical reflection elements, parts of which transmit through the optical reflection elements corresponding to the transmittances of the optical reflection elements to be secondary transmitted lights, and the rests are reflected to be secondary reflected lights. The secondary transmitted lights propagate toward the OTDR and the secondary reflected lights propagate toward the right on the drawing. That is, multiple reflections occur in the sections formed by neighboring two of the optical reflection elements P1, P2, P3, ··· Pn, and the transmitted and reflected lights overlap and propagate through the optical fiber line 1 in both directions.

In this case, if the reflectance of each of the optical reflection elements P1, P2, P3, ··· Pn is, for example, 100%, components of lights transmitting through to the next optical reflection element will be null; and the 100% reflectance is not applicable.

If the reflectance is 50%, the light will be attenuated to about 1/2 every time when the light transmits through one optical reflection element even in consideration for multiple reflections; and the incident light pulse on the last optical reflection element Pn will be attenuated to about (1/2)n. Therefore, the reflectance cannot be raised too high.

The OTDR receives a reflected light pulse of the specific wavelength λ1 and measures the intensity.

Here, a propagation delay time from a moment that the OTDR transmits a light pulse of the specific wavelength λ1 to a moment that the OTDR receives a reflected light pulse is equivalent to a time needed for the light pulse to propagate back and forth between the position where each of the optical reflection elements P1, P2, P3, ··· Pn is interposed in the optical fiber line 1 and the OTDR. And, the position where each of the optical reflection elements P1, P2, P3, ··· Pn is interposed in the optical fiber line 1 is known, that is, the propagation delay time is known in advance. Therefore, the intensity of the reflected light pulse is measured at the time equivalent to the propagation delay time of the reflected light pulse, and on the basis of the measurement the surveillance can be done between a position where an optical reflection element is interposed in the optical fiber line 1 and the OTDR.

That is, if a reflected light is detected with a desired level at a propagation delay time corresponding to a position where an optical reflection element is interposed, the optical fiber line 1 between the position where the optical reflection element is interposed and the OTDR can be judged that there is no abnormality. If a reflected light is not detected, then the optical fiber line 1 between the position where the optical reflection element is interposed and the OTDR can be judged that there occurred any fault.

In this case, the surveillance of the optical fiber line 1 may be performed from the comparison of the reflected light intensity with the one at the time when the optical fiber line 1 was installed.

In this manner, the optical fiber line 1 can be surveyed over 200km. This surveillance method takes only one wavelength for surveillance, and it is preferable if there is a limitation to an adaptable number of wavelengths.

The optical fiber grating as one example capable of constructing the optical reflection elements P1, P2, P3, ··· Pn will now briefly be described with reference to Fig. 6. As intensified ultraviolet (UV) lights are irradiated in two directions, as shown in Fig. 6(B), onto a quartz optical fiber 50 having a core 51 in which a germanium is doped, an interference pattem is produced in a part where the ultraviolet lights are irradiated in both directions. At that moment, a change of composition having the same pattem as the interference pattem is produced in the optical fiber 50, and the refractive index changes in the shape of the pattem. This represents an optical fiber grating.

Fig. 6(B) illustrates a typical reflection characteristics of an optical fiber having an optical fiber grating produced. This figure represents the reflection characteristics when a grating length of the optical fiber is made to be 1.6mm, and shows that lights reflect around the wavelength 1536.5nm. The wavelength bandwidth of 0.1nm to 10nm can be obtained as reflected waves.

Next, the principle of the surveillance method of an optical communication line relating to the second embodiment shown in Fig. 2 will be described.

In this surveillance method, a plurality of the optical reflection elements P1, P2, P3, ··· Pn are interposed, for example, at every specific distance in an optical fiber line 1 as shown in Fig. 2(B). Each of these optical reflection elements P1, P2, P3, ··· Pn reflects only a light signal of a specific wavelength, and the optical fiber gratings are applied to these as an example. Specific wavelengths of light signals that the optical reflection elements P1, P2, P3, ··· Pn each reflect are designed to be λ1, λ2, λ3, ··· λn, different from one another.

In this case, the OTDR transmits light pulses of plural wavelengths λ1, λ2, λ3, ··· λn to the optical fiber line 1. Then, the light pulses of plural wavelengths λ1, λ2, λ3, ··· λn propagate through the optical fiber line 1, and the light pulses each are reflected individually by the optical reflection elements P1, P2, P3, ··· Pn interposed in the optical fiber line 1 to retum toward the transmitter side, as shown in Fig. 2(B). In this case, the reflectance of each of the optical reflection elements P1, P2, P3, ··· Pn can be set to about 100%. This is because only one each of the optical reflection elements P1, P2, P3, ··· Pn each reflecting light pulses of specific wavelengths λ1, λ2, λ3, ··· λn is interposed in the optical fiber line 1.

The OTDR receives reflected lights of the specific wavelengths λ1, λ2, λ3, ··· λn and measures each of the intensities thereof. In an example, the OTDR transmits a light pulse of the specific wavelength λ1 and measures an intensity of the reflected light pulse from the optical reflection element P1 for reflecting the light pulse of the specific wavelength λ1 after a propagation delay time needed for the light pulse to travel back and forth between the OTDR and the position where the optical reflection element P1 is interposed in the optical fiber line 1. From this measurement, the surveillance can be performed between the OTDR and the position where the optical reflection element P1 is interposed in the optical fiber line 1. In the same manner, intensities of reflected lights from the optical reflection elements P2, P3, ··· Pn are measured after each of the propagation delay times needed for each of the light pulses to travel back and forth between the OTDR and each of the positions where the optical reflection elements P2, P3, ··· Pn are interposed in the optical fiber line 1. Based on the measurement, the surveillance can be performed between the OTDR and each of the positions where the optical reflection element P2, P3, ··· Pn are interposed in the optical fiber line 1.

That is, if a reflected light of a specific wavelength is detected with a desired level, the optical fiber line 1 between the position where the optical reflection element for reflecting the specific wavelength is interposed and the OTDR can be judged that there is no abnormality. If a reflected light is not detected, then the optical fiber line 1 between the position where the optical reflection element for reflecting the specific wavelength is interposed and the OTDR can be judged that there occurred any fault.

In this case, the surveillance of the optical fiber line 1 may be performed from the comparison of the reflected light intensity with the one at the time when the optical fiber line 1 was installed.

In this manner, the optical fiber line 1 can be surveyed; and if the reflectance of each of the optical reflection elements P1, P2, P3, ··· Pn is set to about 100%, the length of the optical fiber line 1 is set to 300km, and the propagation loss of the optical fiber line 1 is set to 0.2dB/km, the OTDR will receive a light pulse attenuated by 120dB against a level that the OTDR transmitted. And if the reflectance of each of the optical reflection elements P1, P2, P3, ··· Pn is set to about 1%, the length of the optical fiber line 1 is set to 300km, and the propagation loss of the optical fiber line 1 is set to 0.2dB/km, the OTDR will receive a light pulse attenuated by 140dB against a level that the OTDR transmitted. Accordingly, the optimum reflectance will be decided in consideration of the characteristics of the optical fiber line 1, dynamic range of the OTDR, intensity levels of light pulses transmitted from the OTDR.

The principle of the surveillance method of the present invention has been described hereinbefore, and if the wavelengths that the optical reflection elements reflect are set to those other than the wavelengths of transmission signals, the surveillance method will not influence on the transmission characteristics and the in-service surveillance will be made possible.

Next, Fig. 3 illustrates a construction when the principle of the surveillance method of the optical communication line relating to the second embodiment of the present invention shown in Fig. 2 is applied to a optical communication line and the intensities of reflected lights in that case.

The principle of the surveillance method shown in Fig. 3 is the same as that shown in Fig. 2 described above, and detailed description of the surveillance method will be omitted. In Fig. 3, the optical fiber line 1 is equipped with a remotely pumped optical amplifier 2 which is composed of an erbium doped fiber (EDF) 2-2 and an optical isolator 2-1.

And, the optical reflection elements P1, P2, P3, ··· Pn are not interposed within the range (about 200km) on the optical fiber line 1 that surveillance becomes possible by using the reflection lights and Rayleigh backscatter lights, but are interposed in the range of the optical fiber line 1 that surveillance is impossible by using the OTDR. By way of example, the optical fiber gratings are applied to these optical reflection elements P1, P2, P3, ··· Pn. Specific wavelengths of light signals that the optical reflection elements P1, P2, P3, ··· Pn each reflect are designed to be $\lambda 1$, $\lambda 2$, $\lambda 3$, ··· λn, different from one another. Furthermore, the optical reflection element P1 is disposed inside the remotely pumped optical amplifier 2, and following it, the optical reflection elements P2, P3, ··· Pn are disposed in series toward the transmitter terminal equipment where the OTDR is installed.

Here, as the OTDR transmits a light pulse of the specific wavelength $\lambda 1$, the optical reflection element P1 disposed inside the remotely pumped optical amplifier 2 reflects the light pulse of the wavelength $\lambda 1$ to return the reflected light pulse toward the OTDR. This reflected light pulse is, as shown in Fig. 3(B), reflected at the position where the optical reflection element P1 is interposed. The position where the optical reflection element P1 is interposed is out of the range that the surveillance by the OTDR is possible and weak reflection lights and Rayleigh backscatter lights and the like are buried under noises; and therefore, only the reflected light pulse of the wavelength $\lambda 1$ can be detected as an isolated pulse.

And, as the OTDR transmits a light pulse of the specific wavelength λn, the optical reflection element Pn disposed on the optical fiber line 1 reflects the light pulse of the wavelength λn to return the reflected light pulse toward the OTDR. This reflected light pulse is, as shown in Fig. 3(C), reflected at the position where the optical reflection element Pn is interposed shortly over 200km, and the intensity level of this reflected light pulse is higher than that of the reflected light pulse of the wavelength $\lambda 1$. However, the position where the optical reflection element Pn is interposed is out of the range that the surveillance by the OTDR is possible and weak reflection lights and Rayleigh backscatter lights and the like are buried under noises; and therefore, only the reflected light pulse of the wavelength λn can be detected as an isolated pulse.

Next, as the OTDR transmits a light pulse of the specific wavelength $\lambda 3$, the optical reflection element P3 disposed on the optical fiber line 1 reflects the light pulse of the wavelength $\lambda 3$ to return the reflected light pulse toward the OTDR, as shown in Fig. 3(d).

Furthermore, as the OTDR transmits a light pulse of the specific wavelength $\lambda 2$, the optical reflection element P2 disposed on the optical fiber line 1 reflects the light pulse of the wavelength $\lambda 2$ to return the reflected light pulse toward the OTDR, as shown in Fig. 3(e).

Both of the reflected light pulses are reflected at the positions where the optical reflection elements P2, P3 are interposed over 200km, and weak reflection lights and Rayleigh backscatter lights and the like are buried under noises; and therefore, only the reflected light pulse of the wavelength $\lambda 2$, or $\lambda 3$ can be detected as an isolated pulse.

As clearly observed in Fig. 3(B) - (e), the surveillance method of the optical communication line according to the present invention enables the surveillance in the range of the optical fiber line 1 that the surveillance method by detecting the reflection lights and Rayleigh backscatter lights cannot cover, by measuring the intensities of reflected light pulses.

Next, in the surveillance method of the optical communication line according to the present invention, another embodiment in which an optical amplification means is put under surveillance will be described with reference to Fig. 4.

In an optical communication system shown in Fig.

4(A), one end of a transmitting side optical fiber line 1-1 connects with a transmitter 11 for transmitting a transmission signal of a 1.55μm wavelength band, and the other end connects with a remotely pumped optical amplifier 2. The transmitting side optical fiber line 1-1 is, for example, 300km long.

The output of the remotely pumped optical amplifier 2 connects with one end of a receiving side optical fiber line 1-2 through which the transmission signal of 1.55μm wavelength band propagates. The other end of the receiving side optical fiber line 1-2 connects with a wavelength multiplexer 21 provided on the receiving side.

This wavelength multiplexer 21 receives an pump light of 1.48μm wavelength band that an pump light source 22 supplies, the wavelength multiplexer 21 transmits the pump light of 1.48μm wavelength band to the optical fiber line 1-2, and the pump light propagates through the optical fiber line 1-2 of, for example, 100km long to be received by the remotely pumped optical amplifier 2. Here, an erbium doped fiber (EDF) 2-2 equipped inside the remotely pumped optical amplifier 2 is pumped by the pump light of 1.48μm wavelength band, and accordingly the EDF2-2 amplifies the received transmission signal of 1.55μm wavelength band.

An optical isolator 2-1 equipped inside the remotely pumped optical amplifier 2 is to prevent the deterioration of the transfer characteristics of the remotely pumped optical amplifier 2 due to the reflection lights and Rayleigh backscatter lights and the like, and to control the signal propagation direction.

Furthermore, the remotely pumped optical amplifier 2 is equipped with an optical reflection element R1 interposed on the input of the EDF2-2 and an optical reflection element R2 on the output. The specific wavelengths that the optical reflection elements R1, R2 reflect are λ1, λ2, respectively.

The transmission signal of 1.55μm wavelength band amplified by the remotely pumped optical amplifier 2 propagates through the receiving side optical fiber line 1-2 to be received by the wavelength multiplexer 21, from which the transmission signal is guided to a receiver 23. The receiver 23 demodulates the received transmission signal. Still, the wavelength multiplexer 21 connects with a OTDR 24.

This OTDR 24 transmits light pulses of the wavelength λ1 and λ2 to the receiving side optical fiber line 1-2 through the wavelength multiplexer 21, measures the intensities of the light pulses of the wavelength λ1 and λ2 reflected by the optical reflection elements R1, R2, and thereby surveys the remotely pumped optical amplifier 2. If the wavelength λ1 and λ2 are different from those of the transmission signals multiplexed in wavelength division as shown in Fig. 4(B), in-service surveillance will become possible.

The surveillance method of the remotely pumped optical amplifier 2 will now be described. The OTDR 24 transmits the light pulses of the wavelength λ1 and λ2 to the receiving side optical fiber line 1-2 as shown in Fig. 4(B). The light pulses propagate through the optical fiber line 1-2, reach the remotely pumped optical amplifier 2 and then the light pulse of the wavelength λ2 is reflected by the optical reflection element R2 to reversely propagate through the optical fiber line 1-2 to return to the receiving side.

When the light pulse of the wavelength λ1 reaches the remotely pumped optical amplifier 2, the light pulse transmits through the optical reflection element R2, the light pulse is amplified by the EDF2-2 and afterward reflected by the optical reflection element R1. And, the reflected light pulse is again amplified by the EDF2-2, and transmits through the optical reflection element R2 to reversely propagate through the optical fiber line 1-2 to return to the receiving side.

The reflected light pulse returned to the receiving side is guided to the OTDR 24 through the wavelength multiplexer 21. Fig. 4(C) illustrates an example of waveforms of the reflected light pulses that the OTDR 24 receives. The light pulse of the wavelength λ2 is received after a propagation delay time that the light pulse needs to propagate back and forth through the receiving side optical fiber line 1-2, and the intensity is decreased owing to the propagation loss. The light pulse of the wavelength λ1 is received after the foregoing propagation delay time plus a propagation delay time that the light pulse needs to propagate back and forth between the one end of the optical fiber line 1-2 and the EDF2-2. This light pulse is amplified each time it passes the EDF2-2, and it is received with an increased intensity amplified twice.

The level difference between the received light pulses of the wavelength λ1 and λ2 is equivalent to double of the amplification gain by the EDF2-2; and if the level difference is surveyed, the surveillance of the gain of the remotely pumped optical amplifier 2 will be possible.

Furthermore, the optical reflection elements R1, R2 have the wavelengths different from each other, and there does not occur multiple reflections between the optical reflection element R1 and R2 to deteriorate the transfer characteristics. Accordingly, the reflectance of the optical reflection elements R1, R2 can be set to 100%. And, the reflectance may be lowered if needed.

Fig. 7 illustrates a construction of the OTDR. In this figure, a pulse from a pulse generator 40 drives a variable wavelength light pulse source 41 to generate a laser light pulse of a specific wavelength. The light pulse source 41 is provided with a laser diode LD capable of varying its oscillation wavelength. This light pulse enters an AOM (acoustic optical modulation) optical switch 42, through which the light pulse is transmitted to this optical fiber line 1. The repetition period of this light pulse is set longer than a to-and-fro propagation delay time through the measured optical fiber line 1 to make the light pulse an isolated pulse. The AOM optical switch 42 switches the reflected light pulse, which is guided to a photodetector 44 composed of a photodiode (PD), received and transformed into an electric signal.

This electric signal is amplified by an amplifier 45, converted into a digital signal by an analog/ digital (A/D) converter 46, and enters an equalizing processor 47. The data of reflected lights buried under noises are equalized in the equalizing processor 47, and the processed data are supplied to a microcomputer 48. Thereby, intensity levels of the reflected lights are obtained depending on the distances to the optical reflection elements on the optical fiber line 1, thus waveforms shown in Fig. 3(B) ~ (e) are displayed on a CRT 49.

The AOM optical switch 42 is controlled in switching by an AOM driver 43 to which the pulse from the pulse generator 40 is supplied as a timing signal.

In this case, the OTDR 24 receives not only reflected lights, but also reflection lights and Rayleigh backscatter lights in a slant waveform as shown in Fig. 3(B). The inclination of the waveform of the reflection lights and Rayleigh backscatter lights gives a rate of the propagation loss of the optical fiber line 1. Reading a propagation loss or a distinguished change of a propagation loss from a displayed waveform will give a connection or fracture point of the optical fiber line 1. Furthermore, reading a time (distance) and position of a reflected light and an intensity level and presence of a reflected light will give a fracture point and the like of the optical fiber line 1.

Next, Fig. 5 illustrates a construction of a optical communication system to which the surveillance method of the optical communication line according to the present invention shown in Fig. 3 and 4 is applied.

In the optical communication system, the total length of the optical fiber line is about 400km, and a remotely pumped optical amplifier 2 is interposed in the optical fiber line. A transmitter terminal equipment 10 is provided with a transmitter 11 for transmitting a transmission signal and a OTDR 12 for surveying a transmitting side optical fiber line 1-1.

Furthermore, a receiver terminal equipment 20 is provided with a wavelength multiplexer 21, pump light source 22, receiver 23 for receiving the transmission signal, receiving side optical fiber line 1-2, and a OTDR 24 for surveying the remotely pumped optical amplifier 2.

The surveillance method of the optical communication system shown in Fig. 5 is a combination of the methods shown in Fig. 3 and 4, and the outline of the method will hereafter be described.

As the OTDR 12 transmits a light pulse of a specific wavelength $\lambda 1$ to the transmitting side optical fiber line 1-1, an optical reflection element P1 disposed inside the remotely pumped optical amplifier 2 reflects the light pulse of the wavelength $\lambda 1$. The OTDR 12 receives the reflected light pulse and the reflection lights and Rayleigh backscatter lights at the same time. Thus, the range of about 200km where the optical reflection elements P1 - Pn are not interposed can be surveyed by measuring the intensity of the reflection lights and Rayleigh backscatter lights , the rest about 100km to the remotely pumped optical amplifier 2 can be surveyed from the measurement of the intensity of light reflected by the optical reflection element P1.

And, when the OTDR 12 transmits light pulses of the specific wavelengths $\lambda 2$ - λn, the surveillance on the transmitting side optical fiber line 1-1 can be done to each of the positions where the optical reflection elements P2 - Pn for reflecting the light pulses of the wavelengths $\lambda 2$ - λn, respectively, are interposed.

If there is a light pulse of a specific wavelength that is not received, it is found that there is any fault including a fracture of the line between the optical reflection element for reflecting the specific wavelength and an optical reflection element interposed before the optical reflection element.

As the OTDR 24 equipped in the receiver terminal equipment 20 transmits light pulses of wavelengths $\lambda 1'$, $\lambda 2'$ to a receiving side optical fiber line 1-2 through the wavelength multiplexer 21, the light pulses propagate through the receiving side optical fiber line 1-2, reach the remotely pumped optical amplifier 2, and the light pulse of the wavelength $\lambda 2$ is reflected by the optical reflection element R2.

As the light pulse of the wavelength $\lambda 1$ reaches the remotely pumped optical amplifier 2, it transmits through the optical reflection element R2 and is amplified by the EDF2-2 and then reflected by the optical reflection element R1. And, the reflected light is again amplified by the EDF2-2, transmits through the optical reflection element 2, propagates through the optical fiber line 1-2 in the reverse direction toward the receiving side.

The reflected light pulse retumed to the receiving side is guided to the OTDR 24 through the wavelength multiplexer 21.

Since the level difference between the received light pulses of the wavelengths $\lambda 1$ and $\lambda 2$ is equivalent to double of the amplification gain by the EDF2-2 as described above, the gain of the remotely pumped optical amplifier 2 can be surveyed from the surveillance of this level difference.

The OTDR 24 hereat receives the reflection lights and Rayleigh backscatter lights , and the receiving side optical fiber line 1-2 of about 100km long can be surveyed from reading the waveform of the reflection lights and Rayleigh backscatter lights.

The wavelength of transmission signals propagating through the transmitting side optical fiber line 1-1 and receiving side optical fiber line 1-2 is in 1.55μm band, and the pump light source 22 gives an pump light of 1.48μm band to the remotely pumped optical amplifier 2.

Furthermore, the wavelengths $\lambda 1$ - λn for surveillance are different from the wavelength $\lambda 1'$ and $\lambda 2'$. Setting these wavelengths to wavelengths different from those of the transmission signals will enable in-service surveillance.

Still, the reflectances of the optical reflection elements P1 - Pn and the optical reflection elements R1, R2 can be set to 100%, enabling a long-distance sur-

veillance of an optical fiber line.

The surveillance method of the optical communication line according to the present invention can be applied to detection of faults and locations in fault of an optical fiber line of a long-distance nonrepeating optical communication line, Bi-directional optical communication line, or an optical communication line provided with an optical amplifier repeater, and surveillance of the gain and loss and the like of optical circuits including optical amplifiers and the like interposed in the optical fiber line.

The surveillance method of the optical communication line according to the present invention is constructed as described herein above, and the optical communication line that is too long to cover for the surveillance method by the measurement using the reflection lights and Rayleigh backscatter lights can be surveyed through the whole line.

Furthermore, interposing the optical reflection elements before and behind the optical amplification means and measuring the intensities of reflected lights from the optical reflection elements can measure the level difference given by the optical reflection elements located before and behind the optical amplification means; and therefore, the transfer characteristics of the optical amplification means can be surveyed.

Still, the measurement means of reflected lights from the optical reflection elements can also measure the reflection lights and Rayleigh backscatter lights, and the measurement means of the reflected lights can serve as the measurement means of the reflection lights and Rayleigh backscatter lights.

While the specific embodiments of the present invention have been illustrated and described herein, it is realized that numerous modifications and changes will occur to those skilled in the art. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit and scope of the invention.

Claims

1. A surveillance method of an optical communication line, wherein:

    optical reflection elements are interposed at constant intervals or at a plurality of optional positions in an optical fiber line, in which every optical reflection element reflects only a light signal of one specific wavelength on a constant level;

    the light signal of the one specific wavelength is transmitted to the optical fiber line to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights; and

    from the measurement and/or observation, sections in fault are determined and a state of the line is surveyed.

2. A surveillance method of an optical communication line, wherein:

    optical reflection elements are interposed at constant intervals or at a plurality of optional positions in an optical fiber line, in which each of the optical reflection elements reflects only a light signal of one of specific wavelengths different from one another on a constant level;

    the light signals of the specific wavelengths different from one another that the optical reflection elements reflect are transmitted to the optical fiber line to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights; and

    from the measurement and/or observation, sections in fault are determined and a state of the line is surveyed.

3. A surveillance method of an optical communication line, wherein:

    optical reflection elements are interposed at constant intervals or at a plurality of optional positions in an optical fiber line, in which every optical reflection element reflects only a light signal of one specific wavelength on a constant level;

    optical reflection elements are interposed at constant intervals or at a plurality of optional positions in the optical fiber line, in which each of the optical reflection elements reflects only a light signal of one of specific wavelengths different from one another on a constant level;

    the light signals of the specific wavelengths that the optical reflection elements each reflect are transmitted to the optical fiber line to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights; and

    from the measurement and/or observation, sections in fault are determined and a state of the line is surveyed.

4. A surveillance method of an optical communication line, in an optical fiber line in which an optical fiber

having a rare earth element doped to have an optical amplification function is disposed in the optical fiber line, the surveillance method of an optical communication line, wherein:

optical reflection elements are interposed before and behind the optical fiber having the optical amplification function, in which each of the optical reflection elements reflects only a light signal of one of specific wavelengths different from each other on a constant level;

light signals of the specific wavelengths that the optical reflection elements reflect are transmitted to the optical fiber line to measure each of intensities of reflected lights from the optical reflection elements and/or to observe each of aging characteristics of the intensities of the reflected lights; and

from the measurement and/or observation, a state of operation of the optical fiber having the optical amplification function is surveyed.

5. A surveillance method of an optical communication line, as claimed in claim 1, wherein the optical reflection elements are optical fiber gratings.

6. A surveillance method of an optical communication line, as claimed in claim 2, wherein the optical reflection elements are optical fiber gratings.

7. A surveillance method of an optical communication line, as claimed in claim 3, wherein the optical reflection elements are optical fiber gratings.

8. A surveillance method of an optical communication line, as claimed in claim 4, wherein the optical reflection elements are optical fiber gratings.

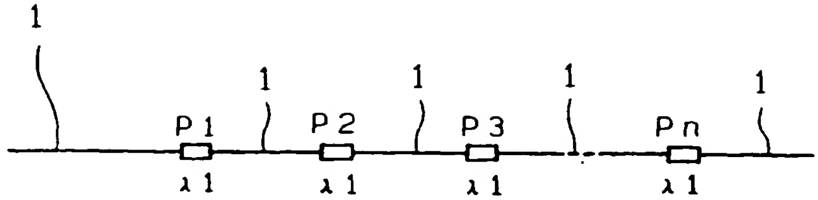

FIG.1 (A)

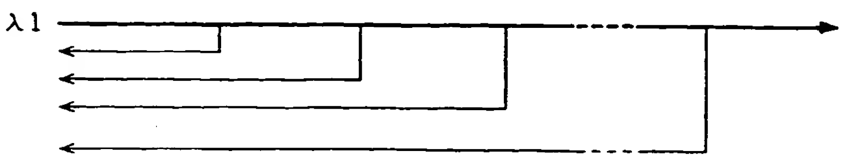

FIG.1 (B)

▭ OPTICAL REFLECTION ELEMENT

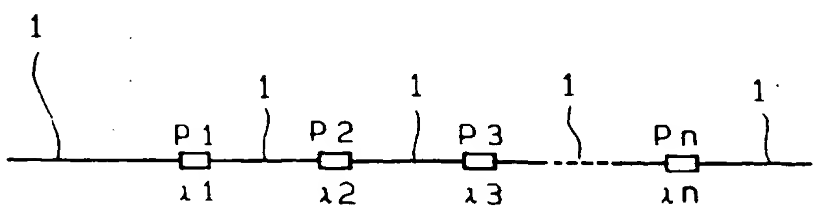

FIG.2 (A)

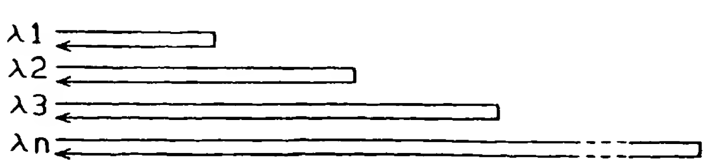

FIG.2 (B)

▭ OPTICAL REFLECTION ELEMENT

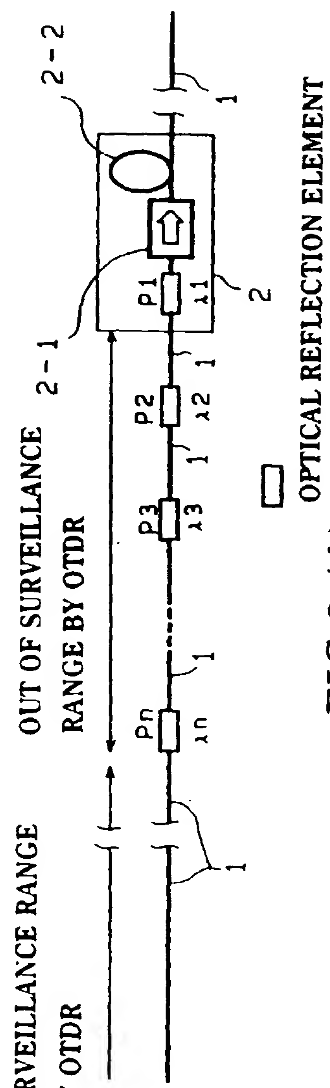

FIG.3 (A)

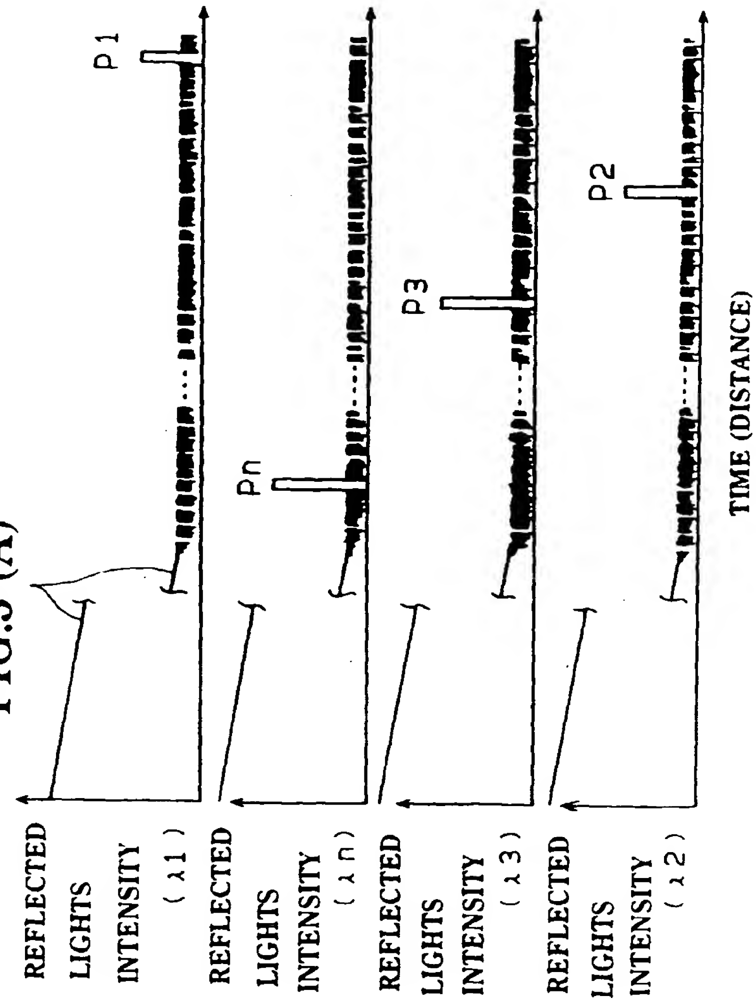

FIG.3 (B)

FIG.3 (C)

FIG.3 (D)

FIG.3 (E)

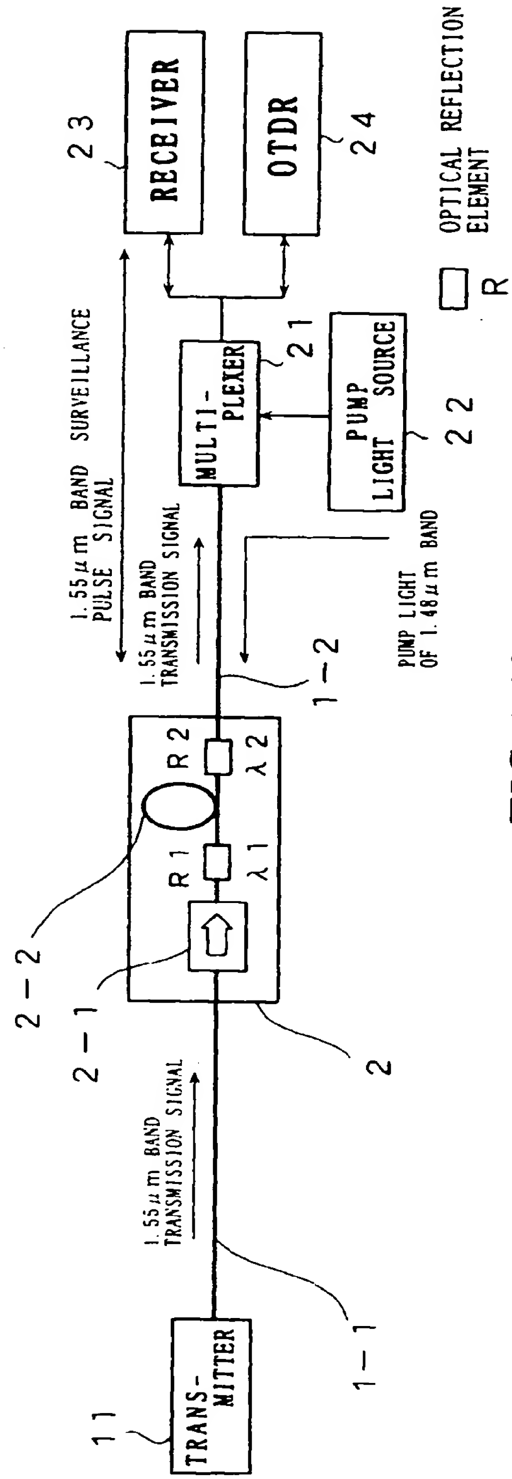

FIG.4 (A)

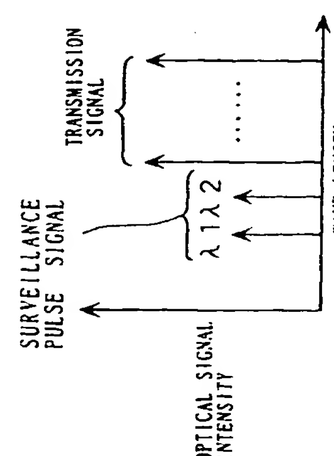

FIG.4 (B)

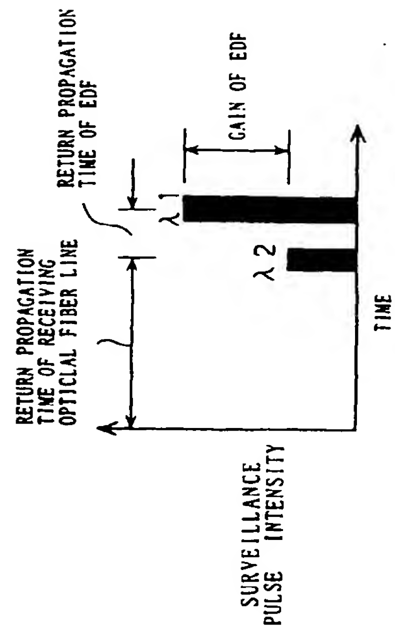

FIG.4 (C)

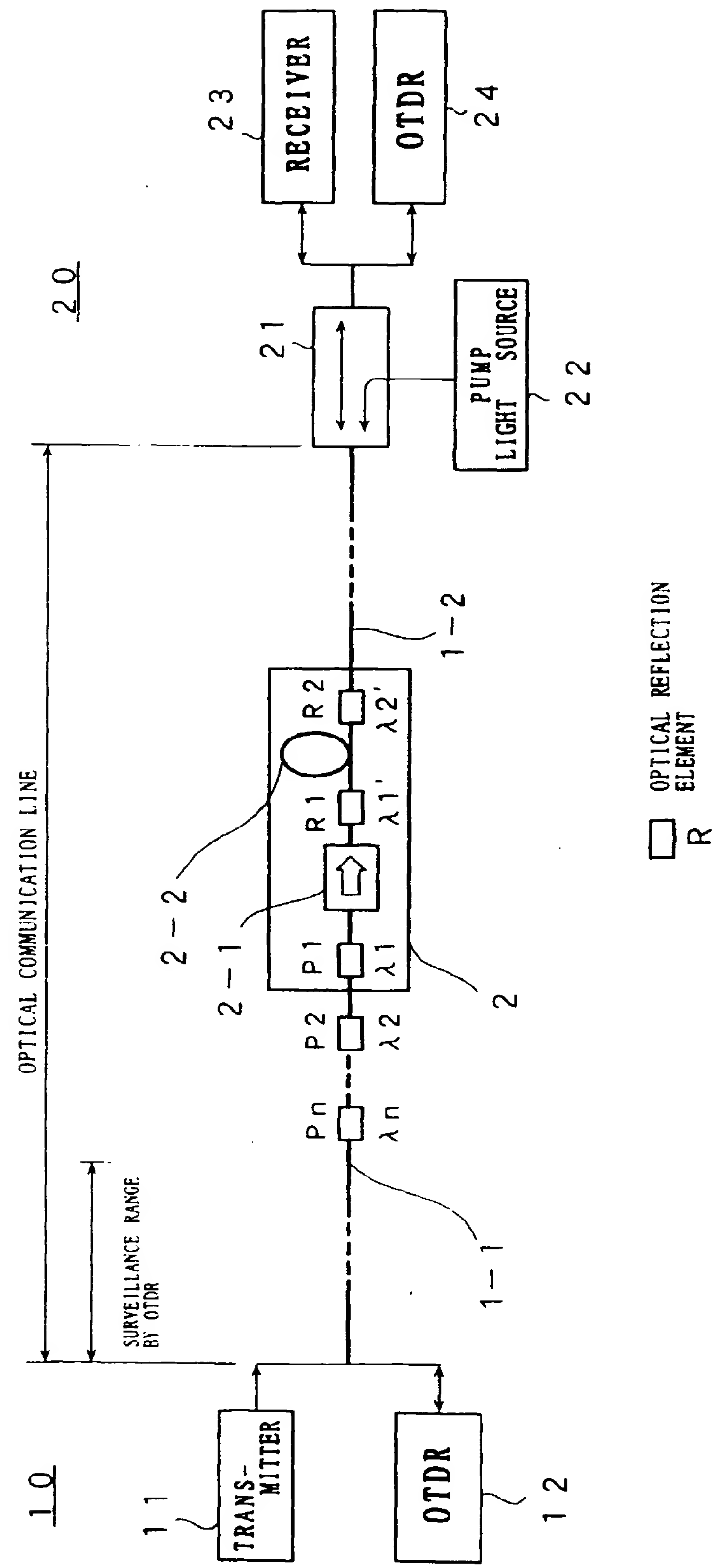
20
RECEIVER
OTDR
23
24
21
PUMP LIGHT SOURCE
22
OPTICAL COMMUNICATION LINE
1-2
R2
λ2'
R1
λ1'
2-2
2-1
P1
λ1
2
P2
λ2
Pn
λn
1-1
SURVEILLANCE RANGE BY OTDR
TRANS-MITTER
OTDR
10
11
12
R OPTICAL REFLECTION ELEMENT

FIG.5

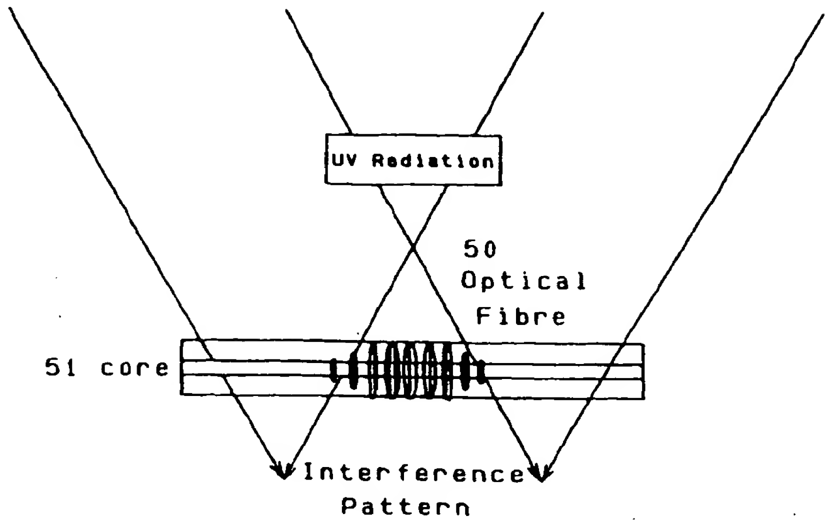
UV Radiation
50
Optical
Fibre
51 core
Interference
Pattern

FIG.6 (A)

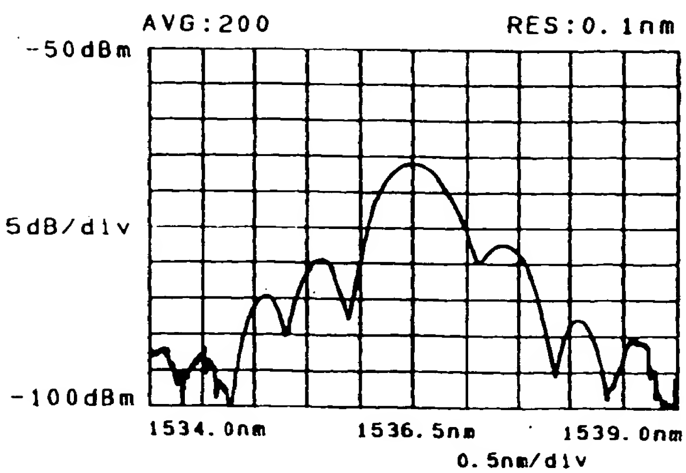
AVG:200
RES:0.1nm
-50dBm
5dB/div
-100dBm
1534.0nm
1536.5nm
1539.0nm
0.5nm/div

FIG.6 (B)

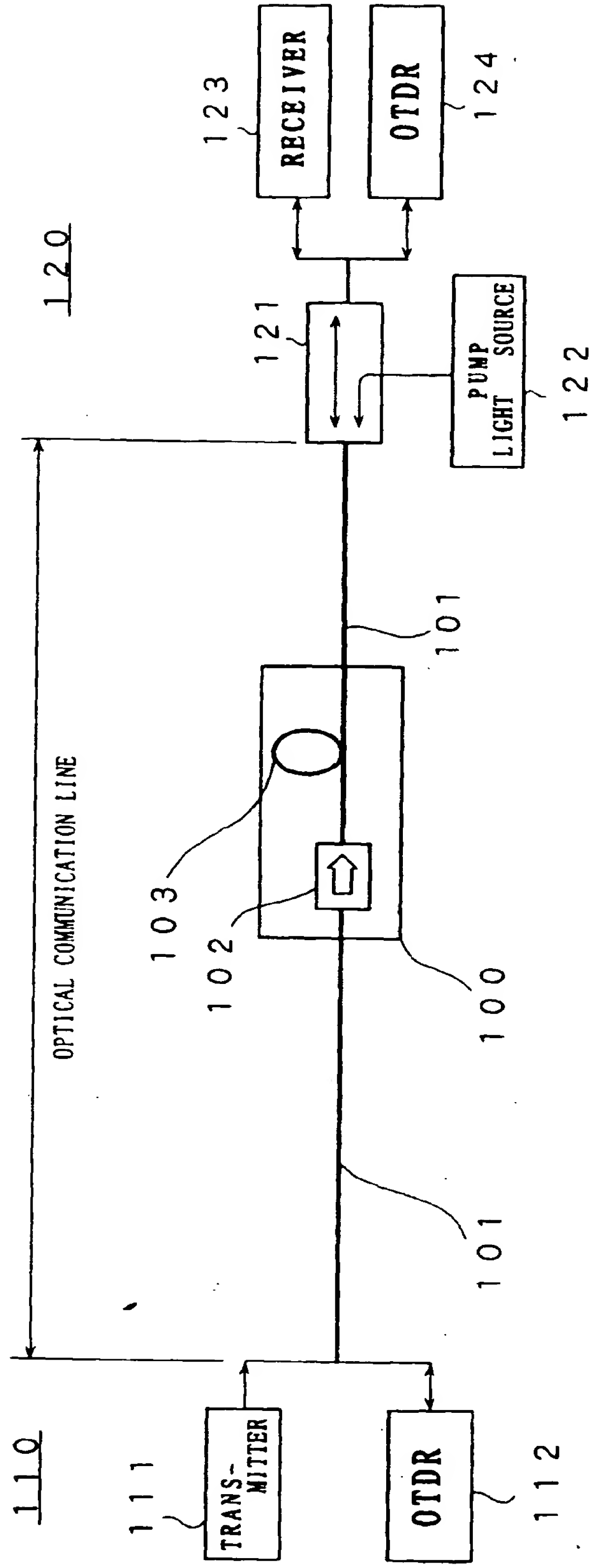
110
111
TRANS-
MITTER
OTDR
112
OPTICAL COMMUNICATION LINE
101
103
102
100
101
120
121
PUMP
LIGHT SOURCE
122
123
RECEIVER
OTDR
124

FIG.8

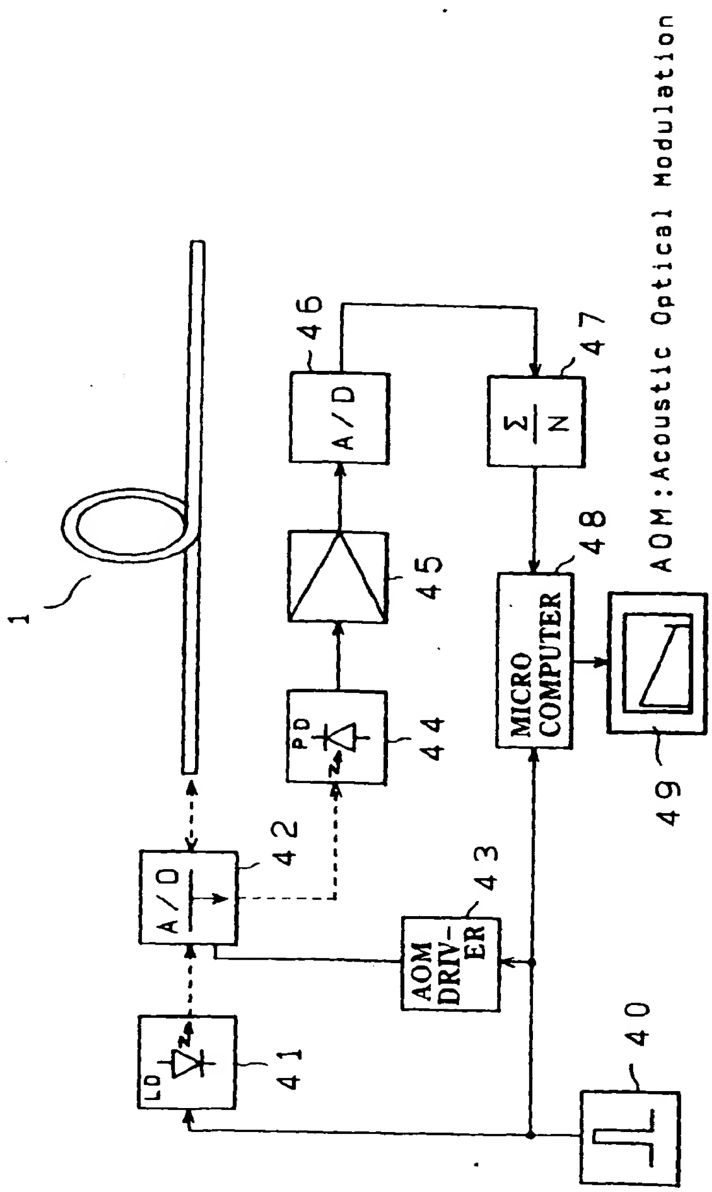
1
LD
41
A/O
42
PD
44
45
A/D
46
Σ
N
47
AOM
DRIV-
ER
43
MICRO
COMPUTER
48
49
40
AOM:Acoustic Optical Modulation

FIG.7

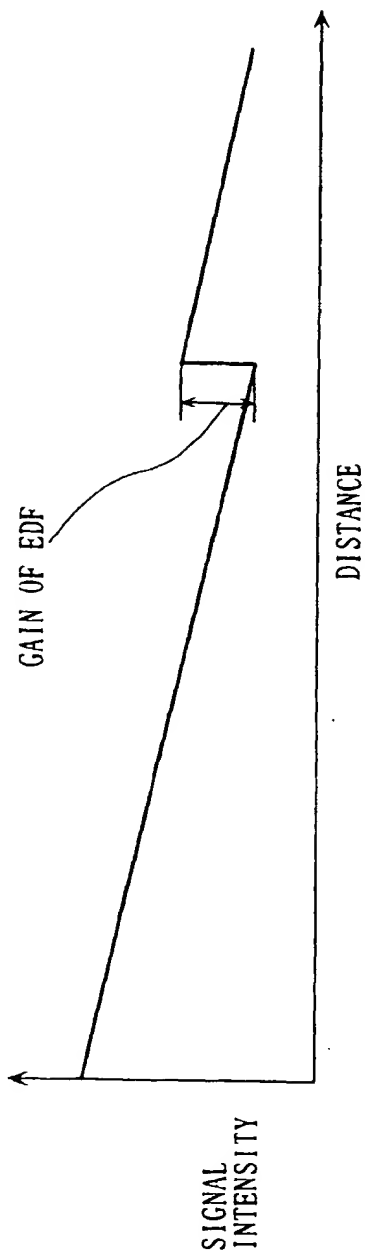
GAIN OF EDF
DISTANCE
SIGNAL
INTENSITY

FIG.9 (A)

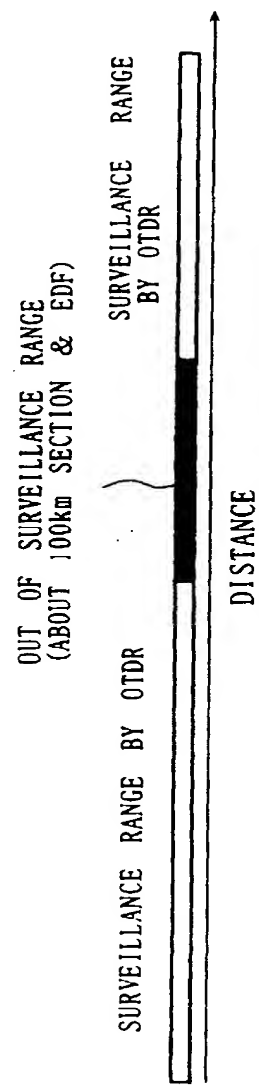
OUT OF SURVEILLANCE RANGE
(ABOUT 100km SECTION & EDF)
SURVEILLANCE RANGE BY OTDR
SURVEILLANCE RANGE
BY OTDR
DISTANCE

FIG.9 (B)